STRUCTURAL VERSUS EXPERIENCED COMPLEXITY:

A NEW PERSPECTIVE ON THE RELATIONSHIP BETWEEN ORGANIZATIONAL COMPLEXITY AND INNOVATION

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Abstract

In this paper, we explore the relationship between organizational complexity and firm-level innovation. We define and operationalize a new construct, experienced complexity, which is the extent to which the organizational environment makes it challenging for decision-makers to do their jobs effectively. We distinguish experienced complexity from structural complexity, which is the elements of the organization, such as the number of reporting lines or integrating mechanisms, that are deliberately put in place to help the organization deliver on its objectives, and we argue that structural complexity correlates positively with firm-level innovation while experienced complexity correlates negatively with innovation. Using a novel dataset combining survey and objective data on 209 large firms, we find support for our arguments.

INTRODUCTION

A long-standing topic of interest in management studies is the relationship between the internal complexity of an organization and outputs, such as innovation, adaptability and profitability (e.g. Ethiraj and Levinthal, 2004; Damanpour, 1996). In this paper we focus on *organizational* complexity, rather than the separate body of work on *technological* complexity which suggests that inventors might face a 'complexity catastrophe' when they attempt to combine highly interdependent technologies (e.g. Fleming and Sorenson, 2001). Organizational complexity is a function of the number of parts in the system and the linkages between them, but these parts "interact in a non-simple way" (Simon, 1962: 468) and as a result complexity brings both benefits (because it enables organizations to do difficult things) and costs (in the form of additional coordination and oversight, as well as unintended consequences). How these benefits and costs net out in practice is hard to specify and predict, and this helps to explain why empirical studies have generated ambiguous and often context-specific findings (e.g. Damanpour, 1996), and why many organizational researchers have used modelling techniques to improve our understanding of cause and effect in complex systems (Rivkin and Siggelkow, 2003; Levinthal, 1997).

Organizational complexity has also attracted considerable attention in the applied business literature in recent years, perhaps because of a number of high-profile failures in large, complex firms such as Enron, Lehman Brothers, BP and Royal Bank of Scotland. Some observers have suggested large firms such as Citibank are "too complex to manage" (Birkinshaw and Heywood, 2009), the implication being that their complexity has contributed to their performance problems, and others have advocated various practical ways of managing their complexity (Gottfredson and Aspinall, 2005; Ashkenas, 2007).

Organizational complexity, in other words, is an important contemporary phenomenon that has deservedly attracted research interest. However, while much progress has been made on understanding the antecedents and consequences of complexity, several gaps remain. First, our understanding of how complexity affects organizational outcomes is still inconclusive. Damanpour (1996) has showed that there are many contingencies affecting the relationship, and it is also possible that inconclusive results have been found because complexity is a "catch-all" construct that needs further specification. Second, we know little about how complexity shapes people's perceptions and behaviors in organizations. In keeping with the burgeoning interest in understanding the micro-foundations of strategy and capability development (Devinney, 2013; Felin and Foss, 2005), we believe there is an opportunity to explore how complexity as an organization-level construct shapes and is shaped by individual-level factors.

These two gaps in knowledge motivate the current study. Rather than taking the usual firm-level perspective on complexity, we offer a complementary individual-level perspective, suggesting that complexity can also be understood as a pattern of stimuli impinging on individuals in their task environment (Wood, 1986: 61). This individual-level cognitive perspective (Fioretti and Visser, 2006; Campbell, 1988) allows us to operationalize a new construct, *experienced complexity*, which is *the extent to which the organizational environment makes it challenging for decision-makers to do their jobs effectively*.

Building on a combination of theoretical arguments and inductive research interviews, we make a conceptual split between *structural complexity,* which is the elements of the organization, such as the number of reporting lines or integrating mechanisms, that are deliberately put in place to help the organization deliver on its objectives (Galbraith, 1995; Tushman and Nadler, 1978), and *experienced complexity*, which is the elements of the organization, such as unclear accountabilities or inefficient processes, that have emerged without the approval or involvement of those at the top of the organization (Leibenstein, 1969) and impinge on the ability of individuals to get their work done effectively.

Building on this conceptual distinction, we develop formal hypotheses linking various dimensions of structural and experienced complexity to firm-level innovation (as one key outcome variable), and we then test these hypotheses using a combination of primary questionnaire-based data (to measure experienced organizational complexity) and secondary data (to measure innovation) on a sample of 209 firms.

The paper makes three contributions. First, we define and operationalize a new construct, experienced complexity. By looking at complexity through the eyes of an individual operating in his or her task environment, we shed light on aspects of the phenomenon that cannot be understood using firm-level data alone. Our approach therefore complements the existing firm-level perspective that is dominant in the literature (Ethiraj and Levinthal, 2004; Damanpour, 1996), and thereby opens up some interesting new avenues for investigation.

Second, our empirical analysis shows that experienced complexity and the more traditional notion of structural complexity have different outcome effects, with structural complexity correlating positively with firm-level innovation, and experienced complexity correlating negatively with innovation. This is an important finding, because it helps to explain some of the inconclusive empirical evidence in prior studies, and it allows us to develop new theory about the relationship between complexity and organizational performance.

Finally, our paper offers a new perspective on an important practical challenge in the world of business. Many large firms today, in such industries as banking, pharmaceuticals and oil and gas, are highly complex, and observers have argued that this complexity has contributed to well-publicized management failures such as the financial crisis and BP's spill in the Gulf of Mexico. This paper provides a useful starting point for helping firms to decompose their activities into those that create intended (and potentially useful) complexity versus those that create unintended (and potentially harmful) complexity, which in turn could steer them towards making improvements in their organizational arrangements in the future.

THEORETICAL BACKGROUND

There are two distinct bodies of research on organization-level complexity, with one body focused primarily on the relationship between structural features of organizations (such as size and formalization) and organization-level outcomes such as innovation and performance, and the other built on insights from complexity science to show how order emerges from the interaction of the many constituent parts of an organization.

The original studies of organizational complexity were conducted in the 1970s, and they operationalized complexity in terms of the various dimensions of differentiation (spatial, occupational, hierarchical, and functional) as well as firm size (Miller and Contay, 1980; Beyer and Trice, 1979; Hall, 1977; Blau, 1970). Consistent with the open systems view of organizations, the overarching proposition behind these studies was that organizations should be designed to match the complexity of the environment in which they were operating (Galbraith, 1982; Thompson, 1967). However, the results of these studies were not entirely conclusive. For example, in a meta-analytic review, Damanpour (1996) showed that structural complexity and size were both positive predictors of firm-level innovation, but with many contingency factors affecting these relationships.

The second wave of organization-level research, building on the theory of complex adaptive systems, showed that complexity is not just a function of the diversity of elements that make up a system, it is also affected by the interdependencies between those elements (Axelrod and Cohen, 2000; Anderson, 1999; Levinthal, 1997; Simon, 1962;). A few studies have shown how real-life organizations exhibit many of the non-linear outcomes predicted by complexity theory (e.g. Brown and Eisenhardt, 1998; Browning et al, 1995). The majority have adopted modelling techniques to play out the likely consequences of simple behavioural rules for organization-level innovation, adaptability and long-term success (Rivkin and Siggelkow, 2003; Levinthal, 1997). For example, one set of studies showed that tightly coupled organizations cannot engage in exploration without foregoing the benefits of exploitation (Rivkin, 2000; Levinthal and Warglien, 1999). An optimal level of complexity is thus achieved by more loosely coupled organizations which can exploit the fruits of past wisdom while exploiting alternative bases of future viability (Levinthal, 1997).

While different in many important respects, these bodies of research share a view of complexity as an attribute of the organization as a whole. For the earlier researchers in the 1970s, complexity was essentially a structural quality of the organization, the result of a set of choices made by the firm's top executives about its size and scope, and its formal structures and systems. For the more recent wave of research, complexity was an emergent property of the organization, the result of many lower-level agents interacting together in ways that created unpredictable outcomes.

But even though considerable progress has been made through these studies, there remain several significant gaps in our knowledge. First, the empirical evidence for how complexity affects organizational outcomes is inconclusive. As Damanpour (1996) showed, the relationship is at best a contingent one, that is, it varies according to various external and internal factors. It is also possible that the inconclusive results have been observed because complexity is a "catch-all" construct that needs further specification. For example, firm size, one important dimension of complexity, has been argued to affect innovation positively because it creates slack, strong technical capabilities and tolerance of failure (Dewar and Dutton, 1986; Kimberly and Evanisko, 1981), but it has also been said to inhibit innovation because it is associated with formal rules and standards (Hitt et al, 1990; Hage, 1980). Similarly, formal rules have been shown to have both coercive and enabling qualities (Adler and Borys, 1996).

Second, we know surprisingly little about how complexity actually shapes the way people behave in organizations. There have been many recent calls for studies of the "micro-foundations" of organizations, on the basis that organization-level constructs, such as complexity, capability or strategy, are shaped by the actions of individuals, and then in turn shape the way those individuals process information and act (Devinney, 2013; Powell and Colyvas, 2008; Felin and Foss, 2005; Whittington, 1996). While the recent complexity literature has done a good job of modelling higher-level outcomes as a result of lower-level actions, the reverse causal link has not been explored. We believe this is a missed opportunity. We still know very little about how complexity affects the perceptions and behaviours of individuals within organizations.

These limitations suggest that a fruitful line of inquiry would be to look more closely at the nature of organizational complexity *as it is perceived and acted on by individuals*. To do this, it is useful to briefly review the individual-level literature on complexity.

Individual-level research on complexity

The behavioural literature on *task complexity* is primarily concerned with understanding how the nature of the task affects an individual's performance and job satisfaction. For example, Wood (1986: 60) described how the essential components of a task are its products, required acts and information cues, and depending on how these are put together the task will be more or less complex. He also derived three dimensions of task complexity: component complexity, coordinative complexity and dynamic complexity. Campbell (1988) identified four different perspectives through which task complexity could be understood, and he used these to derive a typology of complex tasks. He also distinguished between objective and experienced complexity. Several further studies built on these ideas, primarily around understanding the fit between the complexity of a job and the skills and values of the individual doing it (e.g. Shaw and Gupta, 2004; Wilk and Sackett, 1996; Hunter, Schmidt and Judiesch, 1990).

The important insight emerging from the task complexity literature is that how an individual experiences the complexity of their task is a function of three interrelated factors: (a) the intrinsic complexity of the task itself, (b) the capacity and motivation of the individual to cope with complexity, and (c) the level of complexity of the task environment in which the individual is working. While these three factors are very hard to separate empirically, they are conceptually distinct. And for our purposes in this paper it is the third factor, namely, the complexity of the task environment that is relevant. Complexity, according to this view, is the "pattern of stimuli impinging on the individual" (Wood 1986: 61), and the implication is that some organizations create greater complexity through the various information cues experienced by the individual, than others.

The notion that the complexity of the organization shapes the way individuals process information and behave is well established in other bodies of organization theory. For example, in the literature on managerial cognition, organizations are viewed as interpretive systems in which individuals create meaning and action from the stimuli they receive from other parts of the organization (Daft and Weick, 1984; Weick, 1979). And according to the attention based view (Ocasio, 1997; 2011), individuals face more information and stimuli than they can process as bounded-rational individuals, so one of the things executives do is to create structures that seek to focus the attention of individuals on salient issues. In our terms, then, organizations can to some degree manipulate the amount of complexity people are exposed to, and this in turn affects their ability to carry out their tasks effectively.

In sum, these and other studies concerned with individual-level cognition and behaviour help to elucidate what organizational complexity feels like "in practice" which is potentially a useful way of advancing our understanding of the phenomenon (Felin and Foss, 2005; Whittington, 1996). It is recognized that some tasks are inherently more complex than others, and some individuals are more able to soak up complexity than others. But in addition to these factors, the way an organization is designed and managed has a substantial effect on the level of complexity an individual experiences. We therefore propose to develop further Campbell's (1988) concept of "experienced complexity" which refers to how those working in the organization experience it, rather than its structural features.

THEORETICAL DEVELOPMENT

As already discussed, organization theory has traditionally treated complexity as a structural variable, and as an attribute of the organization as a whole. More formally, organizational complexity can be defined as the extent to which an organization has multiple diverse parts and interdependencies between those parts. This definition builds on Simon (1962) and is consistent with the "NK modelling" approach in organization science (Levinthal, 1997; Rivkin and Siggelkow, 2003) where complexity is the product of the variety of elements and the level of linkages between elements.

We believe it is useful to develop a complementary construct, experienced organizational complexity, which is important *because* it affects the way that individual decision-makers do their jobs. As Fioretti and Visser (2006) note, complexity increases the demands on individual decision makers through a cognitive process, i.e. through how those decision makers interpret and make sense of the stimuli they received (Weick, 1979). And as Simon (1962: 481) notes, "how complex or simple a structure is depends critically upon the way in which we describe it." It is therefore the "experienced" nature of organizational complexity that potentially is as important as its objective qualities. Our formal definition is as follows:

Experienced Organizational Complexity is the extent to which the organizational environment makes it challenging for decision makers to do their jobs effectively.

This definition has three components. First, it refers to aspects of the "organizational environment" that impinge on what individuals do, rather than aspects of their specific job or skill-set (Wood, 1986). Experienced complexity is, in other words, an attribute of the organization as a whole, even though it can only be measured through the perceptions of those working in it. Second, complexity from the point of view of decision-makers is anything that makes it more challenging for them to do their jobs effectively, i.e. requiring of additional effort on their part. Third, no assumptions are made in this definition regarding the consequences of complexity for the performance of the organization: It is an empirical question whether experienced complexity affects organizational outcomes in a positive or negative way.

As a next step in our theoretical development, we develop further the conceptual distinction between experienced complexity and the more traditional notion of structural complexity.

Structural complexity is the elements of the organization that were deliberately put in place by those at the top of the organization to help deliver on its objectives. These are the fundamental elements of organization design (Galbraith, 1995; Tushman and Nadler, 1978; Lawrence and Lorsch, 1967), such as the number of products or markets, the number of reporting lines, and the use of integrating mechanisms to enable cross-unit coordination. On the basis that structure follows strategy (Chandler, 1962), these can be viewed as strategic choices made by top executives to deliberately create complexity as a way of servicing multiple customers in multiple markets.

Experienced complexity is the elements of the organization that have arisen without the approval or involvement of those at the top. This is a harder construct to measure, because by definition it is an emergent, rather than designed, property of the organization. The first phase of our empirical research (described below) involved semi-structured interviews with decision-makers in many different firms, and they observed that "complexity is like cholesterol – it has bad and good forms." When pushed further, they pointed to such things as poorly-implemented IT systems, ill-defined responsibilities, overlapping roles, rigid procedures, and so on. These might be viewed simply as examples of inefficient management practices, but they are nonetheless important facets of complexity in terms of what decision makers actually experience in their organizations (and are therefore an integral part of the phenomenon).

Experienced complexity is a relatively new construct in the literature on organizations, but there are several analogous concepts that help to clarify its meaning. For example, organizational slack is known to have both positive and negative manifestations (Singh, 1986; Bourgeois, 1981), bureaucracy has been shown to have both enabling and coercive properties (Adler and Borys,1996), and corporate oversight of business units both creates and destroys value in those units (Goold, Campbell and Alexander, 1994). In all these cases, a structural attribute (slack, bureaucracy, corporate oversight) that is intended to provide benefits also brings certain costs that tend to coexist with it. And these costs are particularly salient when studied from an individual-level perspective. As Adler and Borys (1996: 66) note in their study of bureaucracy, "surely employees' attitudes to formalization depend on the attributes of the type of formalization with which they are confronted?"

There is also a considerable amount of evidence in the literature that inefficient management practices or X-inefficiencies (Leibenstein, 1966) are more prevalent than might be predicted by economic theory. Bloom and van Reenen (2007), for example, have recently documented substantial differences in the quality of management practices even among seemingly similar enterprises, and evidence is amassing that these differences often endure over time, even after they have been identified (Syverson, 2011).

In sum, , we believe one useful way forward in the study of organizational complexity is to look at complexity from the perspective of the decision makers in the organization, through a construct we are calling "experienced complexity" which potentially complements the more established construct of "structural complexity."

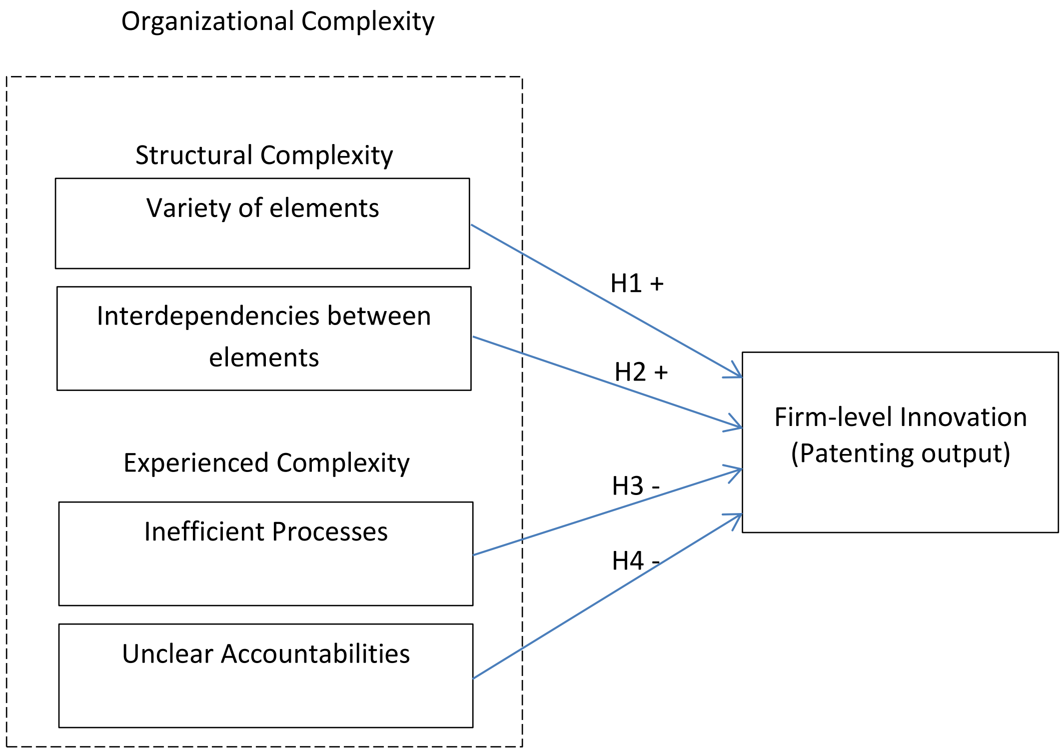
Hypotheses

To push our understanding of organizational complexity forward, it is useful to develop and test some hypotheses that follow from the conceptual arguments developed above. Many possible questions arise from our novel conceptualization, such as the extent to which "experienced" and "structural" complexity overlap, the antecedent conditions that cause experienced complexity, and the mechanisms by which it shapes important organizational consequences. In the interests of keeping the scope of this paper manageable, we make progress in two ways. First, we develop an operational measure of experienced complexity, using a combination of deductive and inductive methods. Second, we conduct a simple empirical test of the relationship between experienced and structural complexity on the one hand, and *firm-level innovation* on the other. We focus on innovation because it has been the most commonly used dependent variable in the complexity literature (Damanpour, 1996), and it fits well with our theoretical arguments about the challenges and opportunities involved in creating new combinations (Kogut and Zander, 1992; Schumpeter, 1934). Nonetheless, we recognize that other output measures are also relevant, and we consider several of them in our robustness checks towards the end of the paper.

Our basic theoretical argument for the link between complexity and innovation works as follows. The organization is conceptualized as a task environment that stimulates decision-makers to act in certain ways, through a combination of structural and contextual cues of varying complexity (Gibson and Birkinshaw, 2004; Ghoshal and Bartlett, 1994; Burgelman, 1983). These cues are then sensed by decision makers, which in turn shapes the way they act individually and collectively (Ocasio, 2012;

Weick, 1979). These actions, in turn, drive a number of organization-level outcomes, such as innovation. Of course, we do not actually measure the individual and collective actions of decision-makers: instead, we measure how they experience the various cues from the task environment, and we correlate these elements of complexity with firm-level innovation (see Figure 1). So we are not able to explicate the underlying mechanisms by which complexity affects innovation, but we still move a step closer than was possible using traditional methods that ignored individual-level perceptions.

Figure 1. Conceptual Framework



Structural Complexity

The structural elements of complexity that are put in place, or "designed" by executives, have been conceptualized in prior research as the variety of elements in the system (e.g. number of lines of business or countries) and the interdependencies between those elements (e.g. multiple reporting lines or cross-cutting processes; Levinthal, 1997). We expect both these sets of factors to have a significant bearing on the way decision makers interpret their task environment.

Consider the variety of elements first. There is an established line of argument in the innovation literature that says innovation occurs through the combination of existing and new knowledge (Schumpeter, 1942), and therefore an important capability for firms seeking to succeed in competitive markets is to search widely, for example through regional networks (Almeida and Kogut, 1999; Saxenian, 1990;), academic and government labs (Cohen et al., 2002), linkages with partner firms (Ahuja and Katila, 2001; Powell et al., 1996; Gulati, 1995), and relationships with suppliers and customers (Dyer, 1994; Day, 1990; von Hippel, 1981). The knowledge these relationships give access to is then used by the firm, in combination with its existing knowledge, to create new outputs. In addition, gaining access to a larger knowledge base may also enhance a firm's absorptive capacity, which in turn makes it easier for future opportunities to be recognized and incorporated (Cohen and Levinthal, 1990).

This line of argument applies in a straightforward way to our conceptual framing. Specifically, the level of variety that individual decision makers experience themselves is likely to have a direct effect on their motivation and capacity to innovate. By being exposed to insights from different parts of the organization, individuals are likely to generate new ideas of their own; they are also likely to encounter others with whom they can potentially work, so that promising ideas can be developed into meaningful innovations. We therefore propose the following hypothesis:

Hypothesis 1. The relationship between the variety of elements within a chosen organizational design and firm-level innovation is positive.

Moving on to the interdependencies between elements, we also expect this relationship with firm-level innovation to be broadly positive. The existence of variety, in terms of access to new sources of knowledge, is necessary for innovation to transpire but it is unlikely to be sufficient. New outputs typically involve recombining existing elements of knowledge into new combinations (Fleming, 1999; Kogut and Zander, 1992; Tushman and Rosenkopf, 1992; Henderson and Clark, 1990; Schumpeter, 1934), and for these new combinations to transpire, it is necessary for the firm to develop mechanisms and processes that enable the disparate parts of the firm to collaborate together (Galbraith, 1995).

Again, this broad argument applies directly to our conceptual framework. Interdependencies manifest themselves as a array of formal and informal linkages between people in an organization, and to the extent that these exist, and are perceived to be impinging on the day-to-day work of decision makers, they will enable the necessary levels of collaboration that make innovation possible (Hansen, 2009; Szulanski, 1995). For instance, common interfaces such as integration teams in case of mergers, meetings within and between the R&D units of different business units, and extensive face-to-face communication with customers and suppliers all enable decision makers to learn about each other's technology and processes (Gerpott, 1995), which in turn is likely to support the development of new combinations. In sum, we proposed the following hypothesis:

Hypothesis 2. The relationship between interdependencies within a chosen organizational design and firm-level innovation is positive.

Experienced complexity

In contrast to structural complexity, the notion of experienced complexity is relatively undeveloped. As noted above, it emerged from the exploratory interviews we conducted at the start of this research project. When we asked *top* executives about the sources of complexity in their organisations, they focused on external constraints (e.g. new legislation) and structural factors (e.g. a matrix structure). But when we asked people three to four levels down, the sources of complexity they talked about were such things as the clarity (or not) of their reporting lines, their accountability for specific activities, and the efficiency (or not) of internal processes. And often their views did *not* correspond to the high-level expectations of top executives: some individuals in objectively-complex roles appeared to be operating without difficulty, while others whose roles looked much simpler expressed great concern about how difficult it was to get anything done.

These insights helped us to conceptualize the notion of *experienced* complexity, which we define as the elements of the organization that have arisen without the approval or involvement of those at the top, and that collectively make it difficult for people to get their work done. This notion that there are *de facto* complexities in many large organizations that compromise internal efficiency has been noted in several strands of literature (e.g. Bloom and van Reenen, 2007; Adler and Borys, 1996; Leibenstein, 1966; Perrow, 1972; Senge, 1990). However, our arguments here are more speculative than those for structural complexity.

Organizations are socio-technical systems in which outcomes are determined by a combination of technical expertise in designing a set of processes and components that yield desirable outputs and social or managerial expertise in generating the necessary level of motivation and cooperation between people (Emery and Trist, 1965; Senge. 1990; Trist and Bamforth, 1951). While certain activities (such as manufacturing pre-designed products) can be specified and managed primarily through technical expertise, other activities require a considerable amount of individual discretion and high levels of motivation. Innovation is certainly one of these activities, which suggests that a great deal of attention needs to be paid to the social or managerial elements of the organization for it to work effectively.

For medium-sized or large organizations (which is our sampling frame in this study), there are formal structures and processes that both enable and constrain individuals in how they work (Adler and Borys, 1996). Such structures constrain individuals in a number of different ways. First, they are often tightly-coupled, so that a small problem in one part of the system can have unpredictable knock-on effects later (Senge, 1990; Perrow, 1984). Second, they are often imperfectly implemented, because of the bounded rationality and limited attention capacity of the individuals responsible for them (Ocasio, 2012; Cyert and March, 1963), and this can hamper communication and coordination across disparate parts of the organization. Third, these constraining features are also likely to reduce the intrinsic motivation of decision makers, and limit the extent to which they use their discretionary time and effort in a way that helps others; all of which is likely to hinder the overall innovation efforts of the firm.

To take our theorizing one step further, it is useful to distinguish conceptually between the vertical and horizontal dimensions of the organization, and to suggest that experienced complexity can arise on both dimensions. The vertical dimension consists of the hierarchical division of the whole into its constituent parts (Hedlund, 1994; Simon, 1962), and the allocation of responsibilities to individuals at each level (Jacques, 1989). When this formal structure is implemented effectively, individuals understand what they are accountable for and how their performance will be evaluated. However, when it is not, there are often overlapping accountabilities and unclear lines of reporting, which requires additional effort to manage. In addition, there are often "turf wars" between units and engagement levels of employees tend to suffer (Brunsson, 2000; Crozier, 1969), all of which will have a detrimental effect on the effective functioning of the organization.

In terms of the link to innovation, unclear accountabilities are likely to have two negative consequences for individual decision makers: first, they will feel constrained in their own work, because there is a lack of clarity about who is responsible for what outputs, and that will limit the level of collaboration between individuals; second, they will be less motivated to put in the discretionary and creative effort that often lies behind innovation (Kahn et al, 1964; Pearce, 1981). Taken together, we therefore expect that unclear accountabilities will be associated with lower firm-level innovation.

Hypothesis 3. The relationship between (perceived) unclear accountabilities and firm-level innovation is negative.

The horizontal dimension refers to the cross-cutting processes through which work is done in large organizations, for example the budgeting process or the order fulfilment process (Davenport, 1993; Hammer, 1990). Horizontal processes are managed through formal procedures, and are one of the defining qualities of bureaucracy (Gouldner, 1954; Weber, 1946). In most large organizations today, they are also automated and standardized to a large degree using Information Technology systems.

When they function effectively, horizontal processes can be enablers of efficiency and productivity, but when they are not they tend to constrain and frustrate employees because they take away individual discretion (Adler and Borys, 1996). To the extent that processes are experienced by decision-makers in the organization as inefficient, we expect they will become a distraction. Decision-makers will therefore end up focusing their discretionary effort on resolving these problems, rather than on the more value-added and creative aspects of their job such as innovation. Thus we predict a negative relationship with innovation:

Hypothesis 4. The relationship between (perceived) inefficient processes and firm-level innovation is negative.

In sum, we propose four direct relationships between elements of organizational complexity and firm-level innovation, two positive and two negative. It should be noted that we do not specify any interaction effects or quadratic relationships here because our understanding of the organizational complexity construct is still very limited. We do however conduct some *post hoc* analysis below to explore whether there are any significant interactions or quadratic relationships in our data.

METHODOLOGY

To test our arguments about organizational complexity, we needed to build a body of data that provided systematic insight into how decision-makers viewed the internal complexity of their firms, which by its nature is not available from public sources. We therefore employed a multi-stage process to develop and administer a survey instrument to executives in a sample of large international firms. The findings from this survey were then used, alongside objective firm-level data, to test our hypotheses.

Sample

We worked with an international advisory company to develop a sample of large firms operating in multiple industries and multiple countries. Our selection criteria were: (a) activities in more than one country and/or industry, to ensure their operating environment was at least moderately complex, (b) industries with significant global competitors, to rule out highly-protected and/or locally-focused industries, (c) at least 1000 employees, to exclude small and medium sized enterprises that often have different managerial and organizational characteristics to large firms, and (d) a stock market listing, to give us access to public-source data.

We sent our survey to a random sample of 1000 firms within this sampling frame, and after excluding responses with missing data, and those where the respondent was more than four levels from the top of the company, we ended up with 209 usable responses, a response rate of 21%. This compares favourably with typical response rates for large-sample international business surveys (Harzing, 1997). Table 1a provides descriptive data for the sample of firms while Table 1b provides an overview of respondents'' characteristics that are available from the survey. We analysed the differences between respondents and non-respondents on measures of size, industry, country of origin, and performance, and no significant differences were uncovered. The survey was completed in 2006.

----------Table 1a and Table 1b----------

To generate responses across a meaningful sample of companies, we elected to use key informants in senior positions whose answers were deemed to be representative of the firm they were working for (Seidler, 1974). This approach is widely used in management research and has been found to be reliable (Crampton and Wagner, 1994). However, we needed to take additional care because our core construct of experienced organizational complexity was new and, like other constructs such as organization culture or customer orientation, subjective in its nature. We therefore took the following precautions. First, we tested the survey in a cross-sectional group of 25 decision-makers in an international resources firm to see how much variation there was in their responses. The average standard deviation per question (on a 5-point scale) was 0.46, suggesting a reasonable degree of convergence in their views. Second, for a third of the sample we got survey responses from a second senior executive, and the inter-rater reliability across the pairs of executives within the same firm was r=0.81, well above the suggested cut-off point of r=0.70 (Cohen et al, 2003). Note that in the actual analysis, we used the more senior executive as the key informant (rather than the average of the ratings from the two executives) because we needed to control for certain individual-level factors in our regression models.

The survey focused on both structural and experienced complexity, and in addition it had questions about the firm's capacity to manage complexity and its overall performance. To avoid concerns about common-method bias, this paper uses the survey findings for the four independent variables and some of the control variables while using the secondary lagged data on innovation (patents) as our main dependent variable.

Measurement Approach

One of the key challenges in this study was the lack of existing measures for organizational complexity. We therefore used a grounded, three-step approach to define and operationalize this construct. First, we conducted interviews with 12 senior executives working in large firms, and we asked what organizational complexity meant to them in practice, and how it affected their ability to deliver on various firm-level objectives. The primary orienting question we asked them was: *What are the aspects of the organizational environment in which you work that make it challenging for you to do your job effectively?* By asking the question in this open-ended way, we were able to group their answers into various categories and to develop an inductive operationalization of organizational complexity. This approach led to the identification of the four constructs, (1) variety of elements (2) interdependencies between elements, (3) unclear accountabilities and (4) inefficient processes.

Second, we assembled a group of six experts, a mix of academics, practitioners and consultants, to review the provisional scales. This process allowed us to refine our chosen measures, and it helped us to link our inductively-generated constructs back to the academic literature. For example, this is where we linked the "variety of elements" and "interdependencies" survey items back to the structural complexity literature. We also identified a set of external factors, such as the level of regulation in the industry, which are used in this paper as control variables. Third, we pilot-tested our provisional list of measures with a further 12 executives, allowing us to fine-tune the wording and to drop those items that did not work.

As a result of this process, we ended up with a four-factor model that fitted the data reasonably well: Comparative fit index (CFI) = 0.90, root mean squared error of approximation (RMSEA) = 0.053 and Chi-squared test = 0.00. All item loadings were as proposed and significant ($p < 0.01$). We also explored two alternative 3-factor models: (a) with unclear accountabilities and inefficient processes bundled under the concept of experienced complexity, and (b) with variety of elements and interdependencies bundled under the concept of structural complexity. Results for these models did not fit the data as well as the four-factor solution: for model (a) comparative fit index (CFI) = 0.72, root mean squared error of approximation (RMSEA) = 0.057 and Chi-squared test = 0.00; for model (b) comparative fit index (CFI) = 0.69, root mean squared error of approximation (RMSEA) = 0.053 and Chi-squared test = 0.00.

To measure innovation, we followed the well-established practice of using the number of published patents as an objective indicator of innovative activity (e.g. Scherer, 1984). Patents have long been recognized as a very rich and potentially fruitful source of data for the study of innovation, as (1) they are directly related to inventiveness, and are granted only for 'non obvious' improvements or solutions with discernible utility; (2) they represent an externally validated measure of technological novelty (Griliches, 1990); (3) they confer property rights upon the assignee and therefore have economic significance (Scherer and Ross, 1990; Kamien and Schwartz, 1982). Patents also correlate well with other measures of innovative output, such as new products (Comanor and Scherer, 1969), innovation and invention counts (Achilladelis et al., 1987), and sales growth (Scherer, 1984). Patents also have their limitations as measures, as some inventions are not patentable, others are not patented, and the inventions that are patented differ greatly in economic value (Griliches, 1990; Trajtenberg, 1990; Cohen and Levin, 1989). Nonetheless, on balance we decided that patent-based measures of firm-level innovation were superior to other options available for the current study.

Until recently, the NBER database on U.S. patents has been the most reliable source of patents used by researchers. This database comprises detailed information on almost 3 million U.S. patents granted between 1963 and 2006, all citations made to these patents between 1975 and 2006, and a reasonably broad match of patents to Compustat. However, it presented several drawbacks for our research. First, it covers only U.S. patents which is a major limitation for our study, since more than a third of the firms in our sample are non U.S. companies. Second, the database stops covering the patents granted after 2006. Third, the reasonably broad match of patents to Compustat presents significant problem given our multi-country sample.

To overcome these problems, we collected a comprehensive dataset of worldwide patenting data for the 209 firms in our sample using the Thomson Innovation database. To our knowledge, this database covers the largest number of patenting jurisdictions in addition to using the most up-to-date corporate tree. Furthermore, to take in account that firms in the sample publish patents under the names of multiple subsidiaries (e.g. Schneider Electric patents under the names of 11 subsidiaries), as well as change their names over time (e.g. 'Motorola Inc.' changed its name to 'Motorola Solutions' in 2010) we use the corporate tree provided by Thomson Innovation while complimenting it with the information on restructuring from firms' 10k reports in the period from 2006 to 2010. This way we build a world-wide patenting database for the firms in our sample avoiding most of the limitations previously mentioned.

Measures

Innovation output (the dependent variable) was measured through the patenting frequency of firms, that is, the number of successful patent applications by a firm in a given year. We measured innovation output as a lagged variable, i.e. the number of patents applied for in 2007, i.e. one year after the survey was completed. We also measured the patent applications two, three and four years after the survey, and we report the results in the robustness tests.

To be more specific, we measured the number of successful patent applications, or granted patents[1]. The granted patent carries the date of the original application. We use this date to assign a granted patent to the particular year when it was originally applied for. Some previous researchers claim that the actual timing of the patented inventions is closer to the application date than to the (subsequent) grant date (Hall et al. 2001). This is so because inventors have a strong incentive to apply for a patent as soon as possible following the completion of the innovation, whereas the grant date depends upon the review process at the Patent Office. Therefore, our procedure permits consistency in the treatment of all patents and controls for differences in delays that may occur in granting patents after the application is filed (Trajtenberg, 1990).

We also used three other measures related to innovation as robustness checks – lagged sales growth, which is frequently discussed as a consequence of innovation, perceived value-added, which was measured using the questionnaire and citations, which represent the value of the patent. We report these results separately as a way of providing additional support to our main arguments.

Variety of elements (structural complexity) is a measure of the scope of activities the firm is involved with. Respondents were asked the following questions: (1) How many different direct customers you have across all operations and business units? (2) How many products and services do you supply? (3) How many different suppliers do you have? (4) How many countries do you operate in? (5) How many industries do you conduct business in? (6) How many ways of making money – business models – there are in your organization? (7) How many M&A has the company made in the last 15 years? (8) How many joint ventures and alliances has the company made in the last 15 years? To ensure that these eight items were weighted approximately equally, each question had a range of possible answers arranged on a five-point scale.

Organizational variety is a formative construct, that is, it derives its meaning from the combined influence of all its constituent items (Bollen, 1989; Mackenzie, Podsakoff and Jarvis, 2005). There is no reason, for example, to expect a firm with many direct customers to also make a large number of acquisitions, yet they both increase the overall level of variety. For this reason, it is not appropriate to calculate a reliability measure, such as Cronbach's Alpha, in the way one would if dealing with a reflective construct. Instead, we report on whether the measures are consistent with our theoretical understanding of these constructs using a Confirmatory Factor Analysis (see earlier discussion).

[1] We chose not to use the data collected on the citations of patents given that, on average, it takes approximately 10 years for a patent to receive 50 percent of its citations and we are focusing on the 2006-2010 period in our analysis.

Interdependencies (structural complexity) is the extent to which disparate parts of the firm are brought together for the purposes of decision making. Respondents were asked the following questions: (1) To what degree decisions require input from multiple business units within the company? (2) To what extent does your organization use matrix structures, which force employees to respond simultaneously to multiple, potentially conflicting, decision premises? (3) To what extent do senior managers in your company have multiple reporting lines? (4) To what extent does your company have multiple dimensions of equal importance at the top management level? (1-disagree completely, 5=agree completely). As above, we conceptualize interdependencies as a formative construct, in that different firms will typically use different mechanisms for building interdependencies between elements (Galbraith, 1973), so we would not expect uniformly high or low scores on these questions.

Unclear accountabilities (experienced complexity) are vertical arrangements in the organization that that unintentionally make it more challenging for decision makers to do their jobs effectively. Respondents were asked to rate the following statements: (1) Accountabilities are often shared in the company, so it is frequently unclear who is responsible for what (2) There is significant duplication of activities across the organizations (3) Target objectives are poorly defined (4) Financial rewards are not clearly tied to targets (1-disagree completely, 5=agree completely).

Inefficient processes (experienced complexity) are horizontal arrangements in the organization that unintentionally make it more challenging for decisions makers to do their jobs effectively. Respondents were asked to rate the following statements: (1) Management processes are inefficient, unclear and require more info (2) Operating processes are inefficient, unclear and require more info (3) The company is not very integrated. Systems and processes are not interlinked, use different data and run on different timetables (4) The IT systems are ineffective; they are overly complex and do not keep pace with company development (1-disagree completely, 5=agree completely).

Control Variables. We include a number of measures commonly used in the analysis of firm-level innovation as controls. Control variables include annual firm research expenditures in millions of dollars (R&D) and firm size measured as total number of employees (Size). We would expect that larger in-house research expenditures would lead to greater patenting output (Henderson and Cockburn, 1996). In terms of size, most studies have reported a positive effect of size on innovation (Chaney and Devinney, 1992; Cohen and Levinthal, 1990), while others have shown a negative effect (Mansfield, 1968), or no effect at all (Clark, Chew, & Fujimoto, 1987). We also include the age of the firm (Age) which is calculated using the founding date available in the Capital IQ database. Similarly, to size, prior research on the effects of age on innovation have been mixed (Sorensen and Stuart, 2000). In addition to the above, we include environmental variables such as munificence, instability and regulation that could influence firm innovation and sector dummy variable to account for industry effects. We also incorporate various individual controls to account for the characteristics of the respondents which may influence how they perceive complexity inside their organization. These are the hierarchical level of the respondent (number of layers below CEO), the tenure of the respondent inside the organization, and function dummy variable to account for differences in the work done by respondents. Lastly, we include the number of industries the firm operates in and international diversification of the firm, to control for some of the objective (as opposed to subjectively experienced) dimensions of variety.

Model Specification

To test our hypotheses, we used OLS regression with Poisson estimation, because the dependent variable (number of patents) is a count variable taking on discrete nonnegative integer values, including zero. We applied the following specification of a Poisson regression model:

$\text{Log}(\text{Patents}_i) = \beta_0 + \beta_i X_i$

where Patents_i is the expected number of patents assigned to firm i, and X_i is a vector of repressors containing the independent and control variables described above. In our Poisson regression, we also opted to obtain robust standard errors for the parameter estimates as recommended by Cameron and Trivedi (2009) to control for mild violation of the distribution assumption that the variance equals the mean. Furthermore, to allow for a meaningful comparison of the variables measured along different scales and to reduce potential collinearity, we standardized most of the control variables before entering them into the regression models.

RESULTS

Table 2 presents the summary statistics and the pair-wise correlation matrix for our measures. Since the sample includes firms from multiple industries, it is not surprising that there is considerable variance on all the key variables such as Patents, R&D, Size, and organizational complexity. We see that the average issued number of patents for the firms in our sample is 386 for 2007. The variables reflecting the hypothesized effects are not very highly correlated among themselves or with the control variables.

----------Table 2----------

Table 3 provides results for our main models using Poisson regression estimators (reported with empirical standard errors). The variables reflecting the hypothesized effects were entered into the regression individually and log-likelihoods are reported for all models. In the analysis presented, the number of patents applied in 2007 and published is the dependent variable. Model 1 in Table 3 presents the base model in which environmental munificence, environmental instability, regulation, R&D expenditure, size, age, number of industries, international diversification, tenure, hierarchical level, sector and respondent function dummies were included as control variables. In models 2-5, we introduced variety, interdependencies, inefficient processes and unclear accountabilities to assess those variables' effects on innovation.

In Hypothesis 1, we propose that variety of elements has a positive relationship with firm-level innovation. This hypothesis was supported, since the linear coefficient for variety in model 2 and model 5 is positive and significant. Hypothesis 2 proposes a positive linear relationship between interdependencies and innovation. In model 3 and model 5 in Table 3, the coefficient for interdependencies is positive and significant as expected, supporting our second hypothesis. In Hypothesis 3 and 4, we predict that inefficient processes and unclear accountabilities have a negative relationship with innovation output. Both of these hypotheses are supported (model 4 and 5). In terms of elasticities of patent counts to our independent variables, we calculate incident rate ratios (IRR values) which are equal to exponentiated coefficients from the output in final model 5 in Table 3. We find that the incident rate of firm-level innovation increases by 42% and 67% for every unit increase in variety and interdependencies, while the incident rate of firm-level innovation decreases by 44% and 37% for every unit increase in inefficient processes and unclear accountabilities respectively.

The effects of the control variables were mostly in line with our expectations and here we discuss only a few of them. The strong result that older firms patent more is not surprising given that previous streams of research found that organizational competence may improve over time (March, 1991; Hannan and Freeman, 1984; Stinchcombe, 1965). Thus, if the passage of time leads to an accumulation of foundational knowledge, organizational competence will increase with age. Similarly, we discover that the executive tenure has a positive and significant relationship with innovation in line with Waldman, Ramirez, House and Puranam (2001) who found that executive tenure had a positive relationship with profit margins. Long tenures are associated with strategic persistence to a course of action (Finkelstein and Hambrick, 1990) and therefore could have a positive influence on firm innovation.

We also conducted an additional analysis in which all the different elements of organizational complexity were bundled together as a single construct (with all elements equally weighted). This was, in essence, a test of our underlying proposition that it would be useful to decompose organizational complexity into structural and experienced components. As model 6 shows, this “catch all” construct had a positive but non-significant relationship with firm-level innovation, which is broadly consistent with Damanpour’s (1989) meta-analysis and provides further support for our conceptual approach here.

Robustness tests We ran several sensitivity tests to check the robustness of the results. One possible concern with our analysis was that the one-year lag between 2006 (when the questionnaire data was collected) and 2007 (for the dependent variable) was not appropriate. We therefore collected patent filing data also for 2006, 2008, 2009 and 2010. For the 2006 data, the results were entirely consistent with what is reported in table 2; for the years 2008-2010 the results were similar but not identical. Specifically, using the 2008 data provided support for Hypotheses 2-4, the 2009 provided support for Hypotheses 1-3, and the 2010 provided support for Hypotheses 1-2.

We also considered other possible firm-level outcome variables, as there are often some concerns raised about the validity of patent data as a measure of innovation. As shown in Table 4, we estimated the main model while including all four elements of organizational complexity, but using two different dependent variables: (1) sales growth in 2007 (one-year time lag) and (2) a subjective measure of value creation (specifically, a questionnaire item, “how effective do you believe this firm has been at creating value?” 1-5 scale). These models yielded findings that were broadly consistent with our findings above. In Model 7 (sales growth), the coefficient for unclear accountabilities was significant at p=.12, and in Model 8 (value creation), the coefficient for variety of elements was significant at p=.26. All other coefficients were significant at levels below p =.05 and in the predicted direction.

----------Table 4----------

We tested the strength of the results by relaxing the assumption that our data fits Poisson’s statistical distribution. To accomplish this, we estimated OLS and negative binomial model of our main model. The OLS and negative binomial results again exhibited very similar pattern as the original results indicating that the results of our hypotheses testing are robust. These last results are not included and are available upon request.

We also explored whether there were more complex patterns in the data than predicted by our hypotheses, so we looked first at possible curvilinear relationships between the independent and dependent variables, as there are arguments in the literature about diminishing returns to increases in complexity. We added squared terms for each of the four independent variables, one at a time, to model 5. However, none of these turned out to be significant. We also explored the possibility of interaction terms between our independent variables, on the basis that these various elements of experienced organizational complexity might work together. However, again, none of the possible interactions were significant so we do not include the results here (available on request from the authors).

Even though we use widely accepted patent-based measures of firm's innovative activity such as patent counts, we realize that patent counts do not reflect the importance, or novelty of a patent. Therefore, we also test our findings with the second metric of innovation that involves measuring the value of a patent by counting the number of citations a patent has received following its approval. The results are presented in Table 5 and they confirm our initial findings.

----------Table 5----------

In terms of understanding causality, a time-lagged dependent variable does not rule out the possibility of reverse causality, i.e. more innovative firms may choose to create greater complexity. But, again, there is an important nuance. It seems highly likely that being innovative would cause a firm to create additional variety (H1) and build interdependencies between parts of the firm (H2), but it seems less likely that being innovative would cause a firm *directly* to increase the clarity of its accountabilities (H3) or the efficiency of its processes (H4). The likelihood of reverse causality being an issue, in other words, varies by hypothesis, and in our view the findings for H3 and H4 are less susceptible to alternative explanations than the findings for H1 and H2. Nonetheless, we are fully aware that this study remains a correlational and not causal analysis.

In sum, the research design (i.e. a cross-sectional, cross-industry survey) that allowed us to answer our research questions also led to some inevitable challenges in interpretation of our results. We addressed these challenges by conducting additional statistical tests wherever possible, and by working through possible alternative interpretations, and accepting that some limitations remain. Hopefully, future research in this area will address some of these limitations using other designs and methods.

DISCUSSION AND CONCLUSIONS

Our primary contribution in this paper is conceptual, in that we operationalize a new construct, experienced complexity, which allows us to look at an established phenomenon (organizational complexity) in a new way. We therefore do not build on structural contingency theory or complexity theory per se; rather, we offer a complementary view, focusing on the individual-level perspective, which potentially provides new insights into the phenomenon that were not available before.

Our theoretical approach was inspired to a large degree by the increasing interest in the microfoundations of organizations, which are "the underlying individual-level and group-level actions that shape strategy, organization, and, more broadly, dynamic capabilities, and lead to the emergence of superior organization-level performance" (Eisenhardt, Furr and Bingham, 2010: 1263). This perspective can be traced back to March and Simon (1958), Nelson and Winter (1982) and others, and it has become increasingly attractive as a way of shedding light on the mechanisms through which firm-level behaviour emerges (Devinney, 2013). Our approach here was to apply this microfoundational logic to the study of organizational complexity. We argued that complexity is to a large degree "in the eye of the beholder," and the way decision-makers in organizations sense and interpret the stimuli in their task environment shapes their subsequent action (Daft and Weick, 1984; Weick, 1979), and thereby generates meaningful consequences at the level of the organization as a whole. This approach opens up some interesting avenues for further research. For example, it would be interesting to examine further the difference between structural and experienced complexity: are some organizations objectively complex, but sufficiently well-managed that they allow people to work in a streamlined and non-challenging way? And are there other organizations that create experienced complexity in the eyes of their employees, even though they are actually doing relatively simple and non-challenging work? Equally, it would be interesting to understand the conditions that create experienced complexity: is it the immediate working environment, as shaped by the organization's leaders, or the external operating environment, that is more important? These are important questions, complementary to the ones investigated here, that should be explored carefully in future research projects.

Our second contribution is the operational separation we made between structural and experienced complexity. At an intuitive level, this distinction may seem obvious, but it is interesting to observe how little consideration previous researchers have given to the experienced aspects of complexity. This, we suspect, is in large part because it represents a form of "bad management" that is not part of the dialogue in many bodies of theory. Adler and Borys (1996: 66) made a similar observation when discussing the costs and benefits of formalization: "Organization theory has had little to say, however, about the criteria that shape subordinates' assessments of rules as "good" and "bad". To the extent that such a distinction is made in the literature, it is as untheorized common sense."

Our view is that rather than ignore the unintended complexity that arises from unclear accountabilities and inefficient systems, we should attempt to build it into our frameworks – both because it explains variation in firm-level outcomes such as patenting, and because it can be manipulated by those running the organization (Moran and Ghoshal, 1996). Again, some interesting future research directions are immediately suggested. For example, why is there often a gap between the way management structures and processes were designed to work and how they actually work? Is the problem one of poor execution, i.e. a lack of effective follow-through from those designing the structures to those who implement them on a day-to-day basis? Or are certain structures inherently more difficult or complex to operate than others? Of course, these are not new questions – studies of modularity in organizational design, for example, provide a useful perspective on the trade-offs between complexity and flexibility (Baldwin and Clark, 2004; Ethiraj and Levinthal, 2004). But by adding in the social dimension explicitly, i.e. in terms of how structures and processes are experienced by those working with them, there is room for significant advances to be made.

The empirical evidence provided useful support for our theoretical arguments. It is interesting to note, first, that the two elements of structural complexity (variety of elements, interdependencies), mirror exactly the two dimensions used in NK models (Levinthal, 1997). This may not seem surprising, but it is worth underlining that NK models are generally developed in a simulated setting, and they assume complexity to be a firm-level attribute, so it is perhaps reassuring to note that "N" and "K" both affect the extent to which decision-makers in organizations experience complexity and find their work challenging. The empirical findings also support our theoretical framework nicely, with the experienced elements of complexity having negative relationships with firm-level innovation (patenting), and the structural elements having positive relationships.

The results also offer some new perspectives on old findings. As noted earlier, when we aggregated all the dimensions of complexity together, the positive and negative effects essentially cancelled each other out, and we were left with a non-significant relationship between complexity and firm-level innovation. Damanpour's (1996) meta-analysis suggested that a better understanding of the contingency factors affecting the complexity-innovation relationship was the best way forward. Our study suggests a different logic: the effect of complexity does not just "depend" on certain external or internal contingencies; rather, it varies accordingly to how well the chosen approach to complexity has been implemented, to maximize its benefits and minimize its costs.

Another interesting angle is to consider how our findings relate to the established notion of diseconomies of scale. It is well-established in the industrial organization literature that as a manufacturing operation grows, its economies of scale are gradually eroded and ultimately outweighed by its diseconomies of scale, such as bureaucratic insularity, communication distortion, incentive limits and excessive specialization (Canback, Samouel and Price, 2006; Williamson, 1981). This argument assumes, essentially, a curvilinear relationship between complexity and performance. In other words, there are certain objective features of the firm that have a positive relationship with performance at low levels of output and a negative relationship at high levels of output. Our approach does not in any way discredit this argument, but it hints at the possibility of disaggregating the elements of complexity so that the positive and negative effects could be analysed separately. This might help, for example, to understand why similar firms often have different cost curves, with some keeping the complexity of their manufacturing process in check at much higher levels than others.

To conclude, our purpose in this paper was to put forward a new way of looking at complexity in organizations, by separating out experienced and structural forms of complexity, and how these shape subsequent actions. However, much remains to be done, and we hope that these ideas and first empirical tests will stimulate others to build on our work and to establish the validity and efficacy of this new perspective.

Tables:

Table 1a: Descriptive data for the sample (209 firms)

Headquarters	n of firms	Business Sector	n of firms	Employees	n of firms
North America	85	Manufacturing	46	<10,000	44
Europe	76	Telecom	37	10,000-50,000	80
Asia	40	IT	34	50,000-100,000	36
Rest of the world	8	Finance	32	>100,000	49
		Pharma & Chemicals	24		
		Retail	9		
		Other	27		

Table 1b: Descriptive data for the sample (209 respondents)

Function	n of respondents	Tenure	n of respondents	Hierarchy level	n of respondents
Finance	42	<2	21	-1	34
Sales	64	2-5	103	-2	55
R&D	9	6-9	85	-3	71
Manufacturing	22	>10	0	-4	49
Other	72				

Table 2: Summary Statistics and Correlation Table

Variable	Obs	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Patents	209	386	958	0.0	3484	1														
2. Variety	209	2.9	0.7	1.2	4.9	0.20*	1													
3. Interdependencies	209	2.7	0.6	1.3	4.4	0.07	0.03	1												
4. Inefficient processes	209	3.1	0.9	1.0	5.0	-0.03	-0.08	0.02	1											
5. Unclear accountabilities	209	2.9	0.5	1.0	4.2	-0.08	-0.06	-0.01	0.30*	1										
6. Environ munificence	209	0.9	0.1	0.6	1.4	-0.01	0.09	0.00	0.00	-0.05	1									
7. Eviron instability	209	1.2	0.1	1.1	2.5	-0.10	-0.03	0.03	0.04	0.00	0.13*	1								
8. Regulation	209	3.6	0.8	1.0	5.0	0.01	0.12*	0.03	-0.10	-0.01	0.22*	-0.08	1							
9. Ln(Age)	209	3.8	1.0	1.0	6.5	0.23*	0.30*	0.00	0.05	-0.05	-0.04	0.04	0.03	1						
10. Ln(R&D)	209	2.7	3.2	0.0	8.9	0.22*	0.27*	-0.10	0.04	-0.02	-0.24*	-0.16*	-0.16	0.15*	1					
11. Ln(Size)	209	3.3	1.5	0.0	6.6	0.22*	0.43*	-0.01	0.07	-0.03	0.07	0.03	0.03	0.32*	0.41*	1				
12. Number of industries	209	4.2	1.8	2.0	8.0	0.20*	0.19*	-0.09	-0.12*	-0.12	-0.01	-0.02	0.09	0.35*	0.41*	0.20*	1			
13. Internat. diversification	209	0.7	0.6	-0.6	2.0	0.04	0.10	-0.04	0.07	0.04	-0.25*	-0.10	-0.20*	0.43*	0.17*	0.12*	0.13*	1		
14. Tenure	209	5.3	2.6	1.0	9.0	0.07	0.19*	-0.01	0.00	-0.02	0.08	0.00	-0.02	0.14*	0.20*	0.17*	0.10	0.05	1	
15. Hierarchy level	209	2.7	1.0	1.0	4.0	-0.07	0.01	0.07	0.10	-0.04	0.14*	-0.01	0.03	-0.02	-0.01	0.13*	0.02	-0.07	0.07	1

Table 3: Poisson regression results with Patents

DV: Patents	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variety		0.396**	0.346**	0.350**	0.351**	
		(0.186)	(0.176)	(0.165)	(0.169)	
Interdependencies			0.427*	0.429*	0.514**	
			(0.235)	(0.250)	(0.249)	
Inefficient processes				-0.758***	-0.587**	
				(0.259)	(0.272)	
Unclear accountabilities					-0.464**	
					(0.210)	
Overall complexity						0.249
						(0.331)
Environ munificence	2.170	2.238	2.392	2.503*	2.551**	2.279
	(1.493)	(1.508)	(1.503)	(1.333)	(1.286)	(1.581)
Eviron instability	-1.335	-1.331	-1.527*	-1.254	-1.599*	-1.333
	(0.886)	(0.832)	(0.848)	(0.837)	(0.890)	(0.862)
Regulation	-0.0509	-0.0856	-0.0517	-0.0551	-0.0444	-0.0518
	(0.231)	(0.216)	(0.209)	(0.191)	(0.189)	(0.234)
Ln (R&D)	0.0331	0.0355	0.0490	0.0351	0.0278	0.0413
	(0.0471)	(0.0479)	(0.0464)	(0.0449)	(0.0439)	(0.0441)
Ln (Size)	0.0968	0.0307	0.0161	-0.0112	-0.00405	0.0669
	(0.104)	(0.102)	(0.0958)	(0.0936)	(0.0899)	(0.111)
Ln (Age)	0.561**	0.534**	0.568**	0.619**	0.644*	0.571**
	(0.152)	(0.142)	(0.143)	(0.156)	(0.167)	(0.149)
Number of industries	0.122	0.120	0.0906	0.103	0.0842	0.112
	(0.128)	(0.127)	(0.123)	(0.109)	(0.108)	(0.126)
International diversification	-0.256	-0.268	-0.188	-0.135	-0.101	-0.225
	(0.392)	(0.397)	(0.419)	(0.419)	(0.394)	(0.405)
Tenure	0.109**	0.101*	0.0986*	0.112**	0.117**	0.109**
	(0.0554)	(0.0534)	(0.0542)	(0.0498)	(0.0535)	(0.0547)
Hierarchical level	-0.148	-0.121	-0.125	-0.0711	-0.0638	-0.143
	(0.121)	(0.116)	(0.115)	(0.116)	(0.115)	(0.117)
Constant	-0.0909	-1.008	-1.804	-2.302	-2.187	-0.762
	(1.900)	(1.939)	(1.961)	(1.884)	(1.883)	(2.217)
Log likelihood	-91886.085	-89567.393	-87053.149	-82399.747	-79607.09	-99180.41
Observations	209	209	209	209	209	209
Sector Dummies	Included	Included	Included	Included	Included	Included
Respondent Function Dummies	Included	Included	Included	Included	Included	Included

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: OLS regression results with Sales Growth and Value Capture

	Model 7	Model 8
DV:	Sales Growth 2007	Value Capture
Variety	0.0400*	0.202
	(0.0229)	(0.179)
Interdependencies	0.0429*	0.328*
	(0.0266)	(0.190)
Inefficient processes	-0.0493*	-1.045***
	(0.0292)	(0.246)
Unclear accountabilities	-0.0384	-0.743***
	(0.0252)	(0.192)
Environ munificence	-0.00957	-0.933
	(0.161)	(1.216)
Eviron instability	-0.0274	0.383
	(0.0597)	(1.043)
Regulation	-0.0182	0.104
	(0.0233)	(0.147)
Ln (R&D)	0.00997*	-0.00442
	(0.00586)	(0.0497)
Ln (Size)	-0.00972	-0.0708
	(0.0105)	(0.0987)
Ln (Age)	-0.0331**	0.111
	(0.0167)	(0.149)
Number of industries	0.0152	-0.0183
	(0.0122)	(0.102)
International diversification	-0.0944**	0.145
	(0.0407)	(0.288)
Tenure	-0.0107*	0.0154
	(0.00587)	(0.0483)
Hierarchical level	0.0105	0.112
	(0.0147)	(0.124)
Constant	0.236	4.674**
	(0.185)	(2.132)
R-squared	0.505	0.279
Log pseudolikelihood		
Observations	209	209
Sector Dummies	Included	Included
Respondent Function Dummies	Included	Included
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Table 5: Poisson regression results with Citations

DV: Citations	**Model 9**	**Model 10**	**Model 11**	**Model 12**	**Model 13**	**Model 14**
Variety		0.360*	0.305*	0.308*	0.308*	
		(0.186)	(0.176)	(0.165)	(0.170)	
Interdependencies			0.455*	0.455*	0.539**	
			(0.235)	(0.250)	(0.251)	
Inefficient processes				-0.715***	-0.546**	
				(0.256)	(0.269)	
Unclear accountabilities					-0.458**	
					(0.206)	
Overall complexity						0.248
						(0.331)
Environ munificence	2.217	2.262	2.431*	2.527*	2.565**	2.323
	(1.475)	(1.485)	(1.475)	(1.315)	(1.271)	(1.553)
Eviron instability	-1.399	-1.379	-1.586*	-1.324	-1.664*	-1.394
	(0.897)	(0.843)	(0.860)	(0.852)	(0.905)	(0.872)
Regulation	-0.0416	-0.0746	-0.0412	-0.0412	-0.0290	-0.0443
	(0.226)	(0.213)	(0.206)	(0.190)	(0.188)	(0.230)
Ln (R&D)	0.0339	0.0358	0.0502	0.0370	0.0303	0.0418
	(0.0479)	(0.0487)	(0.0466)	(0.0451)	(0.0443)	(0.0449)
Ln (Size)	0.0885	0.0298	0.0142	-0.0109	-0.00377	0.0589
	(0.102)	(0.102)	(0.0947)	(0.0926)	(0.0894)	(0.110)
Ln (Age)	0.567***	0.541***	0.578***	0.627***	0.650***	0.577***
	(0.150)	(0.141)	(0.143)	(0.156)	(0.166)	(0.147)
Number of industries	0.133	0.130	0.0983	0.107	0.0885	0.123
	(0.125)	(0.124)	(0.120)	(0.108)	(0.108)	(0.123)
International diversification	-0.283	-0.291	-0.207	-0.148	-0.122	-0.252
	(0.380)	(0.385)	(0.408)	(0.407)	(0.383)	(0.394)
Tenure	0.101*	0.0945*	0.0924*	0.104**	0.110**	0.101*
	(0.0546)	(0.0530)	(0.0539)	(0.0498)	(0.0533)	(0.0540)
CEO level	-0.165	-0.141	-0.145	-0.0929	-0.0859	-0.160
	(0.119)	(0.115)	(0.115)	(0.116)	(0.115)	(0.115)
Constant	1.097	0.265	-0.580	-1.044	-0.909	0.432
	(1.873)	(1.915)	(1.935)	(1.848)	(1.841)	(2.191)
Log pseudolikelihood	-266879.2	-261184.62	-254507.67	-241779.6	-234325.3	-265493.5
Observations	209	209	209	209	209	209
Sector Dummies	Included	Included	Included	Included	Included	Included
Respondent Function Dummies	Included	Included	Included	Included	Included	Included

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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